# *ANALYSIS AND REPORTING OF DIFFUSE EMISSIONS FROM LANSCE*

**Purpose**

This Meteorology and Air Quality Group (MAQ) procedure describes the process for calculating diffuse emissions of gaseous radionuclides from the Los Alamos Neutron Science Center (LANSCE).

**Scope**

This procedure applies to the methods of calculating airborne radiological emissions from diffuse (non-point) sources at LANSCE. Some of these non-point sources have potential to meet monitoring criteria put forth in the National Emission Standards for Hazardous Air Pollutants (NESHAPs), as set forth in 40 CFR 61.

**In this procedure**

This procedure addresses the following major topics:



**Hazard Control Plan**

The hazard evaluation associated with this work is addressed in HCP-MAQ-Office Work.

**Signatures**

| Prepared by: | Date: |
| --- | --- |
| Dave P Fuehne<br>Dave Fuehne, MAQ Rad-NESHAP Project Leader | 2/14/03 |
| Approved by:<br>Terry Morgan<br>Terry Morgan, MAQ QA Officer | Date:<br>2/24/03 |
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02/12/03

# General information about this procedure

**Attachments**

This procedure has the following attachment:

| Number | Attachment Title | No. of pages |
|---|---|---|
| 1 | LANSCE Diffuse Source Technical Basis Document | 17 |

**History of revision**

This table lists the revision history and effective dates of this procedure.

| Revision | Date | Description of Changes |
|---|---|---|
| 0 | 6/3/1996 | New document, issued under LANSCE-FM document control as 53FMP 104-08.0. |
| 1 | 7/13/00 | Reformatted and brought under MAQ document control; corrected minor errors. |
| 2 | 2/28/03 | Converted ESH-17 references to MAQ as appropriate; included peer review requirements; added information about the 1L Service Area diffuse source. |

**Who requires training to this procedure?**

The following personnel require training before implementing this procedure:

- Any member of RRES or LANSCE divisions involved in calculation of diffuse emissions from LANSCE.

Annual retraining is required and will be by self-study ("reading") training.

**Training method**

The training method for this procedure is "**self-study**" (**reading**) and is documented in accordance with the procedure for training (MAQ-024).

**Prerequisites**

In addition to training to this procedure, the following training is required before performing work to this procedure:

- MAQ-011, "Logbook Use and Control"

# **General information about this procedure**, continued

**Definitions specific to this procedure**

LANSCE: The Los Alamos Neutron Science Center, formerly known as the Los Alamos Clinton P. Anderson Meson Physics Facility (LAMPF), located at Technical Area 53 of Los Alamos National Laboratory. The facility accelerates a proton beam at energies of up to 800 MeV, at currents up to 1 milliampere. Emissions from the facility are primarily air that is made radioactive by various interactions with the proton beam.

Diffuse emissions: Releases of radioactivity that are not from a point source (see definition of point source in MAQ-RN). Diffuse emissions at LANSCE typically come from buildings along the main beam line, where air activation is highest.

EPICS: The Experimental Physics and Industrial Control System. This system is used by the Central Control Room (CCR) at LANSCE to monitor and archive instrument readings and equipment status throughout the facility. Used in conjunction with the Data Scan system and DSRP.

DSRP: The Data Scan Re-Play system. Data Scan is a software system used by the LANSCE Central Control Room (CCR) to monitor and record data from various instruments around the accelerator complex. DSRP is a user-friendly method to retrieve plotted and/or tabulated data from the Data Scan system. Data Scan receives data from diffuse source instrumentation via EPICS.

Facility operation: Memo ESH-17:96-291, "Sampling and Reporting Requirements for LANSCE," dated July 9, 1996, defines monitoring and reporting requirements for TA-53 emissions monitoring facility. Sampling for particulate & vapor activation products must be carried out at all times. Gaseous emission monitoring from the ES-3 stack and diffuse monitoring of the beam switchyard (by the SY Kanne chamber system) must occur when any beam is delivered to the switchyard or beyond. When beam is delivered down Line A, diffuse monitoring must occur for designated areas. When beam is delivered down Line D, gaseous emissions monitoring at the ES-2 stack must take place.

# **General information about this procedure**, continued

**References**

The following documents are referenced in this procedure:

- Title 40 of the Code of Federal Regulations, Part 61, Subpart H, "National Emission Standards for Emission of Radionuclides Other than Radon from Department of Energy Facilities," referred to as 40 CFR 61.
- MAQ-011, "Logbook Use and Control"
- MAQ-024, "Personnel Training"
- MAQ-501, "Dose Assessment Using CAP88"
- MAQ-604, "Performance Testing of the Kanne Air-Flow-Through Ionization Chambers"
- MAQ-RN, "Quality Assurance Project Plan for the Rad-NESHAP Compliance Project"
- "Operational experience with Kanne ionization chambers." J. E. Hoy, *Health Physics*, volume 6, pp. 203-210, 1961.
- Memo ESH-17:96-291, "Sampling and Reporting Requirements for LANSCE," July 9, 1996.

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**Note**

Actions specified within this procedure, unless preceded with "should" or "may," are to be considered mandatory guidance (i.e., "shall").

# General Overview of Process

**Regulatory requirements**

40 CFR 61.93b(4)(i) requires monitoring of any emission source that has the potential to release radionuclides at levels which can cause an effective dose equivalent in excess of 0.1 millirem per year. Based on LANSCE operating parameters, certain non-point sources have the potential to meet this emissions level.

**Source of radioactive air**

The LANSCE ion beams and secondary particles can interact with the air that surrounds the beam line and target cells, making it radioactive. This air can migrate into surrounding buildings, from which it can escape to the environment.

**Monitored sources**

The diffuse sources that historically have been monitored at LANSCE are all along the primary beam line, designated Line A. The sources are primarily buildings. The sources and their designations are: Area A (AA), Area A-East (AAE), the switchyard (SY), and the Isotope Production building (IP).

The 1L Service Area, which contains equipment supporting the 1L Target, has been monitored since 2000. This is due to potential releases of activated gases from the 1L Target water cooling system.

Other portions of the linear accelerator beam tunnel have been monitored in the past, with no activity detected. Likewise, other areas of LANSCE that use lower-intensity beams have been monitored, but potential emissions levels are below monitoring & reporting requirements.

Certain areas have potential for radioactive gas generation and buildup, but are vented through a monitored stack. This includes the Proton Storage Ring (PSR) and Target 4 tunnel, both of which are indirectly exhausted through ES-2.

**Monitoring methods**

Each diffuse source is monitored by one or more Kanne flow-through air ionization chamber(s). These fifty-liter Kanne chambers are highly sensitive to the low levels of radioactivity typical of diffuse measurements. Response of the Kanne chambers to concentrations of radioactive gas can be calculated, and this calculated value compared with values measured at similar systems used at the monitored stacks. A general overview of Kanne chamber construction, operation, and response can be found in an article by J. E. Hoy in *Health Physics,* 1961.

*Continued on next page.*

# General Overview of Process, continued

**Monitoring methods,** *continued*

Current output from the Kanne chambers is measured by electrometers. The electrometer output is recorded on strip charts, recording the log of the current vs. time. These strip charts are automatically marked with the date and time every four hours, to aid in analysis. In addition, the EPICS & DSRP systems are used to monitor and record some electrometer signals electronically, along with beam current, date and time, and other parameters.

**Kanne chamber testing**

Prior to use in diffuse emissions measurements, each Kanne chamber system and associated electronics should be performance tested in accordance with procedure MAQ-604.

If necessary, conversion equations should be developed to recorded data (on strip charts or electronically) to actual current input to the electrometer. Any correction factors so developed shall be documented in the diffuse emissions report, along with all assumptions used in their generation.

**Determining emissions**

Using the Kanne chambers, the ambient building radioactive air concentrations are determined. The outflow of air from each building is determined, through measurement or estimation. The building activity is multiplied by the outflow to find the released activity for the time period of interest.

**Calculating offsite dose from diffuse emissions**

MAQ staff will calculate offsite dose from the emission using the CAP-88 dose assessment program, as described in procedure MAQ-501. Inputs to the code include the released activity, average release height of each diffuse source, and meteorological information (wind direction, speed, etc.).

**Frequency of diffuse emissions calculations**

Diffuse emissions are calculated annually, based on a calendar year. The resulting dose is added onto the LANSCE annual total at the end of the year. If analysis over a different time period is desired, designated personnel can carry out this procedure when directed by group management.

# Calculation of Diffuse Emissions

**Identify sources**

Identify all potential diffuse sources, in conjunction with ESH-1 and LANSCE operations personnel.

For any beam delivered down Line A, B, C, or D, the Beam Switchyard must be monitored. If beam is delivered to the A6 beam stop, then Area A-East and the Isotope Production building need monitoring. If targets are used in Area A (A1 or A2), then Area A will also require monitoring. When the 1L Target's cooling water systems have potential to "off-gas" into the 1L Service Area, this room requires monitoring. Other sources are monitored as needed, as determined by staff.

**Obtain records**

Records of Kanne chamber readings exist on strip charts (maintained by TA-53 Emissions staff) and electronically on the DSRP system. Either record system, or a combination of both, may be used to determine annual emissions.

If using electronic records, spot-check the records with the strip chart data from the same time period to ensure agreement between the two recording methods. As described previously, thoroughly document in the diffuse emissions report any conversion equations or other assumptions used in the analysis of these records.

**Calculate integrated Kanne current**

Each Kanne chamber system records a current, in picoamperes. This signal is recorded on strip charts by the chamber, and may also be archived by the EPICS/DSRP network.

Using either recording system, integrate the current over the time of interest, to find a total charge collected (in picocoulombs).

For certain diffuse sources (e.g., Area A), the Kanne signal must be analyzed in order to separate the actual current reading from background levels. Methodology for this process is detailed in the LANSCE Diffuse Source Analysis Technical Basis Document (Attachment 1).

# **Calculation of Diffuse Emissions**, continued

**Convert charge to activity**

Using the calibration constant determined for the Kanne chambers, convert the charge collected to an activity per unit flow rate.

This constant will be in units of microcuries per picoampere per cubic centimeter (μCi/(pA*cm$^3$)), which can also be described as microcuries per picocoulomb per [cubic centimeter per second] (microCi/(pC*cm$^3$/sec)). A historical value of 2.62E-6 microCi/(pC*cm$^3$/sec) was used for reports prior to 1998. A measured value of 2.84E-6 microCi/(pC*cm$^3$/sec) has been used for reports since 1998.

Multiplying the charge collected (pC) by this constant gives an activity per unit release rate (microCi/(cm$^3$/s)).

**Find diffuse source outflow**

Diffuse source outflows are determined from flow measurements and by engineering judgment. In the past, measurements have been made by Johnson Controls, Inc. personnel (LANL's engineering contractor) and LANSCE staff members. Effects of influencing parameters, such as sealing of building leaks and wind conditions, were evaluated by LANSCE-7 staff members.

Outflows are found in units of actual cubic feet per minute (cfm, converted for average temperature and pressure effects). For the analysis, convert this flow rate to cubic centimeters per second.

Methodologies for determining building outflows of each diffuse source is described in the Diffuse Source Analysis TBD (Attachment 1). The outflows of the "standard" diffuse sources, under typical operating conditions, are listed below. Note that annual changes in meteorology could affect these values. Consult the Diffuse Source TBD for more information.

| **Diffuse Source** | **Outflow (cfm & cm$^3$/sec)** | |
|---|---|---|
| Beam Switchyard (SY) | 900 cfm | 4.25E5 cm$^3$/sec |
| 1L Target Service Area | 12,000 cfm | 5.66E6 cm$^3$/sec |
| Area A building (AA) | 115,000 cfm | 5.43E7 cm$^3$/sec |
| Area A-East building (AAE) | 3800 cfm | 1.79E6 cm$^3$/sec |
| Isotope Production building (IP) | 41 cfm | 1.93E4 cm$^3$/sec |

**Calculate the released activity**

For each source, multiply the flow rate by the activity per unit flow rate to obtain the source's total released activity, in units of microcuries (microCi).

**Repeat for each source**

Repeat the above steps for each diffuse source of airborne activity.

# Reporting of Diffuse Emissions

**Diffuse emissions composition**

In 1993, LANSCE-7 personnel determined the radiological composition of the diffuse sources at various times throughout the LANSCE run cycle, using gamma ray analysis of ambient air at each source. The average composition was 96% positron emitters (assumed to be all carbon-11), and 4% argon-41. This composition remains a conservative assumption.

**Diffuse source release height**

The Diffuse Emissions Technical Basis Document (Attachment 1) contains information regarding the effective release heights of the different sources. This information is required for CAP88 analysis of the releases. These values are reproduced below.

| Diffuse Source | Release Elevation | Release Height Above Ground |
|---|---|---|
| Beam Switchyard (SY) | 2124 m | 0 m |
| IL Service Area (1LSA) | 2128 m | 4 m |
| Area A building (AA) | 2131 m | 7 m |
| Area A-East building (AAE) | 2136 m | 12 m |
| Isotope Production building (IP) | 2124 m | 0 m |

**Diffuse emissions report**

Generate a diffuse emissions report for each report period (typically, a calendar year) and submit this report to the MAQ Rad-NESHAP Project Leader.

Ensure the diffuse emissions report contains the following information:

- Monitored sources
- Duration of monitoring
- Released activity for each source
- Outflow rate for each source
- Release height for each source
- A description of the charge integration methodology (e.g., use of chart records, EPICS/DSRP, etc.)
- Description of the monitoring methods & instrumentation used
- Wind rose to determine meteorological effects on outflow
- A description of all calculations & assumptions used in the report
- Documentation of peer review incorporated into the analysis & report

# **Reporting of Diffuse Emissions**, continued

**Determining dose from diffuse releases**

A member of MAQ will use the reported activity and other parameters for each source to run CAP88 (see MAQ-501) and determine dose from diffuse releases.

Ensure the meteorological file used in CAP88 analysis uses meteorological conditions for the actual beam operating period under analysis. For example, if the run cycle for 1996 is August 1 to November 30 1996, generate a meteorological file based on weather data from only that time interval.

**Peer review of diffuse emissions calculations & report**

According to MAQ-RN, independent peer review must be done for 100% of all hand-entered data, and 10% of all electronically copied data. Additionally, calculation processes must be verified annually.

If electronic files and spreadsheets are used to simplify calculations, obtain an independent peer review of each file's calculations, including conversion equations, start/stop times, summations, etc.

Peer review must also occur for any summations between files, the final report, etc.

# Records resulting from this procedure

**Records**

The following records generated as a result of this procedure are to be submitted as records to the records coordinator:

- The diffuse emissions report and all its attachments
- Kanne chamber strip charts showing recorded current from each monitored source (if equipped with chart recorder). These chart records are maintained by MAQ staff at TA-53, in the Radioactive Air Emissions Measurements Records Center
- Spreadsheet analyses of the integrated current for each monitored source. Summary reports of the data are included in the annual diffuse emissions report; raw data is maintained electronically by the TA-53 RAEM staff.

Click here to record "self-study" training to this procedure.

# *LANSCE DIFFUSE SOURCE TECHNICAL BASIS DOCUMENT*

## *I: Purpose*

This document was originally part of the 1995 Diffuse Emissions report and describes the technical basis for methods used to measure diffuse (non-point) radioactive air emissions from the Los Alamos Neutron Science Center (LANSCE), located at Technical Area 53, Los Alamos National Laboratory.

The methods for monitoring emissions from diffuse sources described in this document were collected from various memos and supporting documentation written by personnel in LANSCE-7 (formerly AOT-7), ESH-1, and P-25.

## *II: Overview*

### A: Facility description

LANSCE is a linear proton accelerator, generating beams of 800 MeV protons and $H^-$ ions at currents of up to one milliampere. Targets placed in the beam produce particles that are used for various research projects. Interactions of the primary beam and secondary particles with air produce radioactive air, some of which is released from the facility.

### B: Types of radioactive air emissions sources

Air emissions are divided into two source groups. Point sources are emissions from a stack, vent, fume hood, or other single forced-air locations. Non-point sources, called diffuse sources, involve emissions of airborne radioactivity that are not discharged through a forced ventilation system via a stack or vent. Diffuse sources also include emissions that are distributed over a large area, such as a pond or building.

### C: LANSCE diffuse emissions

Although most of the radioactive air emitted from LANSCE is vented out monitored stacks, a measurable amount escapes from the high-current beam line into surrounding buildings. This radioactive air can then be emitted into the environment. Federal regulations (40 CFR 61 Subpart H) requires any *point* source whose emissions can potentially cause a member of the public to receive 0.1 millirem of dose annually to be continuously monitored. As yet, no federal regulations explicitly cover diffuse emissions, but it is prudent to monitor those diffuse emissions that meet these emissions criteria. The Quality Assurance Project Plan for the LANL Rad-NESHAPs project (MAQ-RN) and the FFCA require that “significant non-point emissions of activated gases . . . will be determined by other FFCA approved means”

Diffuse sources are primarily located along the main proton beam line, designated as Line A. The primary diffuse sources and their designations are as follows: the Area-A building (AA), the Area A-East building (AAE), the beam switchyard (SY), and the Isotope Production facility (IP). Another source that was monitored in 1995 was the Line A beam tunnel below Area A-East (A4/A5). Other sites are monitored and analyzed based on staff member evaluation of their potential for emissions. This evaluation is based on knowledge of operating parameters for each individual beam operation cycle.

The monitored sites are all locations where the potential for activation of air and other components exists. At the target cells in Area A, secondary particles produced by interactions of the beam with the targets can activate surrounding air, shielding, or other components. Note that this occurs only if target(s) are in place at the A1 or A2 target cells; Area A has no detectable activity when these target cells are empty.

In Area A-East, direct air activation by the proton beam occurs immediately prior to the termination of the Line A beam in the A6 beam stop. This air escapes into both the Area A-East building and the Isotope Production facility, both of which must be monitored during delivery of beam to the A6 beam stop.

Monitoring the switchyard is important due to the potential for beam loss in the area during operations, as well as high concentrations of radioactive air during the “Switchyard Direct” mode of operation. In SY Direct mode, low current beam is used to tune the accelerator, and the beam is terminated in the switchyard beam stop. This causes higher levels of air activation than is seen during routine beam operations. In fact, a majority of the SY diffuse emissions occurs during these SY Direct tuning operations.

Other areas in the A6 region have been examined in the past. The Line A tunnel at A4/A5 has points at which air can enter and exit the tunnel and become subject to activation. However, emissions from the area were shown to be quite low during measurements in 1995 (less than 5% of either A-East or the IP building). Likewise, the E225 cave off of the A6 beam stop was measured in 1994, with a similar very low emissions result. These emissions are “accounted for” through consistent conservative estimates in the A-East and IP emissions.

The 1L Service Area has been a source of diffuse emissions since 2000. The water coolant system pumps were moved from the target cell (exhausted through the monitored ES-2 stack) into the 1LSA, which is ventilated by a HVAC system that exhausts through the roof of the mechanical equipment building (TA-53-7-200). Pressure relief operations can result in off-gassing from these water pumps, releasing radioactive air into the room. This radioactive air will be released to the environment via HVAC exhaust.

## D: Topics covered in this document

Section III of this document covers general comments on diffuse emissions monitoring principles and how they apply to LANSCE. Section IV details measuring diffuse source activity levels with Kanne flow-through ionization chambers. For some buildings, such as Area A and Area A-East, the recorded Kanne chamber current is made of multiple components, necessitating further analysis of the Kanne chamber signal to determine true ambient air activity. The final section involves determining air outflows from buildings. While some sources have easily measured outflows, others are dependent on meteorological conditions and other variables.

# *III: Notes on diffuse emissions monitoring*

## A: Instrumentation

To monitor radioactive air concentrations in buildings, fifty-liter Kanne flow-through ionization chambers are used. The large volume provides a measurable current signal for recording the low radioactive air concentrations found in typical diffuse source situations. The current from the ionization chamber is displayed on a meter and recorded on a semi-log strip chart (log current vs. time). The strip chart is automatically marked with the date and time every four hours for ease in analyzing the chart. A description of Kanne chambers by J. E. Hoy can be found in *Health Physics*, volume 6 (1961), pp. 203-210. Details on Kanne chamber sensitivities can be found in MAQ-RN, the Quality Assurance Project Plan for Rad-NESHAPs Compliance.

## B: Monitoring buildings

It is not practical to continuously measure radioactive air concentration throughout a large building. When possible, dominant outflows are monitored in order to find emitted air concentrations. In other situations, monitoring locations should provide a representative sample of ambient building conditions.

For the Area A building, two monitoring locations along the catwalks that run around the perimeter of the building at approximately mid-height (23 feet above the experimental area floor) were chosen. The Kanne chambers are located on the north catwalk near the east end of Area A and on the south catwalk at the west end, and are designated Area A-North and Area A-South, respectively. Each chamber is used to separately determine radioactive air concentrations for Area A, and the results are averaged together. The locations were picked so that the great majority of the Area A building would be monitored, via room shine or air migration, by one of the chambers (more on this below).

While monitoring Area A during typical operating conditions, the Kanne chambers monitor air locally around the chamber. Additionally, the chambers are subject to gamma radiation “shine” from ambient room air and prompt radiation originating from the proton beam. More information on separating the different components is given in section IV, below. To monitor building concentration, it is important to know the ambient concentration of radioactive room air (the “room shine”) as well as the concentration in local air sampled by the Kanne chamber. Plots show that the air concentration sampled locally around the chamber is related to the ambient concentration of radioactive air within the building. Since a correlation between the local monitored air and the ambient room air is demonstrated, the two-point monitoring of Area A is shown to provide a representative sample of Area A concentrations. The process detailed in Section IV describes how to find the relationship between the different components.

Further demonstrations of representative sampling in Area A were done in 1994 by using a portable Kanne chamber to monitor different locations and elevations throughout Area A. Although the radioactive concentrations at the rafter level were higher than catwalk levels, releases at this height (~16 meters) result in a lower offsite dose (determined by CAP-88 calculations). A variety of assumptions of airflow distributions with respect to elevation were performed, and the highest offsite doses resulted from 100% of emissions occurring at the catwalk elevation (~ 26 feet above ground; 23 feet for catwalk elevation and 3 feet for the height of the Kanne chamber). When examining the room at different lateral locations (at the same elevation), concentration differences were found to have negligible effect on emissions.

Other diffuse sources are monitored at a representative location. For example, Area A-East is monitored directly above the "doghouse," a concrete shield-block structure surrounding the beam stop. Extensive studies done in 1993 showed this location to be of higher concentration than other locations in A-East; using this higher value for concentration determinations provides a conservative estimate of diffuse emissions.

## C: Activity distribution

Ideal diffuse source conditions include uniform distribution of activity throughout the room or building being monitored. When there is uniform distribution, leakage from buildings can be determined using recommendations and techniques set forth by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE). In the case of non-uniform distributions, estimates and measurements must be made to determine relative concentration levels.

Area A's ventilation provides mixing of building air before diffuse release. Differences in the north and south Kanne chamber readings are indicative of differing activity levels at the catwalk. Differences in activity levels on the two Kanne chambers may be due to the close proximity of the north Kanne to the A2 target cell. A study performed in 1992 demonstrated that air undergoes a great deal of movement throughout Area A (Master of Science thesis by N. D. Montgomery, 1993). Since the target cells A1 and A2 (the primary sources of radioactive air generation in Area A) are located along the central east-west axis of Area A and far from exterior walls, there is no opportunity for radioactive air to escape without being subjected to mixing and monitoring.

From the elevated positions on the Area A catwalk , each chamber is able to "view" almost the entire building volume. Areas hidden from one chamber, such as on the experimental area floor on the opposite side of the shielded beam line, are "visible" to the other chamber. Ambient room air radiation (referred to as "room shine" above) provides an indication of radiation levels throughout the room. A "hot pocket" of radioactive air, even though it may not be in the vicinity of the Kanne chambers, will still be detected by one or both of the chambers as room shine.

The IP building is a small enclosed structure. Measurements at different locations showed the same concentration. The source of activity for the IP building is the A6 beam stop which is closely coupled to the IP building through the IP stringer housing and a common shield wall. Measurements showed that the concentration in the stringer housing is the same as the room.

The beam switchyard is larger and its primary source (the A1 target cell) is far away (about 200 ft.) from any release point. Diffusion, along with the natural air changes during operating periods, allow for sufficient mixing before release to the atmosphere.

Area A-East is a location where non-homogeneous mixing occurs. As noted in section V, below, the air in the eastern third of the building has activity levels typically three times higher than the remainder of the building. Since diffuse outflows are distributed throughout the building, a factor of one third is used to account for the non-uniformity of the radioactive air concentrations. This is detailed in the section on outflow from Area A-East.

The primary emissions source in the 1L Service Area is the water pump area in the southeast corner of the room, while the exhaust is in the north wall, west side. The monitoring location can affect calculated activity (e.g., at the source vs. at the exhaust point). Until further measurements are made, assume a uniform activity distribution.

## D: Diffuse emissions control

Area A has another parameter affecting its diffuse emissions. The ambient temperature inside the building determines the amount of radioactive air that escapes from the A1 and A2 target cells.

Air in the target cells is made radioactive through interactions with secondary particles produced from beam interactions. Beam interactions heat the shielding surrounding the targets, in turn heating the air. Any cracks in the shielding (between blocks, around doors, etc.) will create a chimney effect, drawing warm radioactive air from the target cells into Area A. Through convection, the relatively cooler room air drives the warmer air from the target cells and into the Area A building. The warm gas also has potential to rise directly into the room and escape without the typical delay expected, thus releasing more short-lived nuclides and more activity than predicted.

To control this convection, the ambient temperature in Area A is kept at an artificially high level (~85 degrees Fahrenheit) with the heating and ventilation (HV) system. During hot summer months and when the heating system is on, diffuse emissions (as indicated by the magnitude of the “fresh air drops” described in Section IV, below) are very slight. The higher-than-normal Area A temperatures keep the radioactive air contained inside the target cells, where it decays or is evacuated out through the ES-03 monitored stack. During summer nights, or on cooler days when Area A is not heated, the fresh air drops (and related room concentrations) are much larger.

In another method of control, sealing material was placed over cracks between shielding blocks and around doors to reduce chimney effects. This combination of temperature control and sealing migration pathways delays migration of air into Area A and eliminates most short-lived radionuclides from diffuse emission concerns. Under current configurations, the age of radioactive air in Area A is about 20 minutes.

When Area A is heated, confining radioactive air to the target cells, stack suction on the target cells can be reduced. This reduces the number of curies emitted through the stack without increasing diffuse emissions. With less suction, the radioactive air generated in the target cells is retained in the cells longer and has more time to decay away before it is evacuated out of the ES-03 stack. From an emissions standpoint, it is therefore best to keep the temperature of Area A as high as possible during beam operation.

One problem with heating Area A is the effect of high temperature on the electronics used in the various experiments conducted in Area A. Keeping temperatures in the area artificially high can have negative effects on the sensitivity and reliability of instrumentation. A balance between allowable temperature and emissions is maintained to find the most efficient operating situation.

### E: Radionuclide composition

Using a high-purity germanium (HPGe) detector, the radionuclide composition was measured for radioactive air in several of the diffuse sources. When air is sampled next to the Area A target cells, it is characteristically "younger" than the air in the rest of the building. The age of radioactive air (since production) is found by age dating the air, which involves measuring the ratio of $^{41}Ar$ to the 511 keV gammas. As noted, the average age of the air in Area A is about 20 minutes, with similar results obtained for Area A-East. Decay curves for IP air measured in 1994 show it to contain $^{13}N$, $^{11}C$, and $^{41}Ar$, with no younger component.

Radioactive air released through diffuse emissions is therefore assumed to be all $^{11}C$ and $^{41}Ar$. This assumption is conservative, since $^{15}O$, $^{13}N$, and $^{11}C$ have similar decay mechanisms (positron emissions & annihilation to 511 keV gamma rays). The longer half-life of $^{11}C$ results in a higher dose received at the maximally exposed individual. The measured composition of 96% $^{11}C$ and 4% $^{41}Ar$ has been used for all reports since 1994, and remains a conservative assumption.

## *IV: Measuring diffuse source activity*

### A: Kanne chambers

As described in Section III.A, Kanne flow-through ionization chambers are used to continuously record a current proportional to the radioactivity of the sampled air. This current is integrated over the run cycle and converted to an activity concentration for each diffuse source.

### B: Analysis Of Kanne Chamber Signals

For some of the diffuse sources mentioned in section II.C, no analysis of the recorded signal is necessary beyond simple integration of the real-time current to determine charge collected. Area A and Area A-East are the exceptions.

**1. Area A analysis**

Area A requires significant analysis and interpretation of chart data. At the present time, the most effective way to perform the analysis is through manual transcription of the strip chart data, making notes of chart events, such as prompt drops and fresh air drops (both described later). It is possible that macros or analysis algorithms could be developed to perform the analysis more quickly, but they have not been developed and validated at the time of this writing. Therefore, manual transcription must still be performed, for at least a representative sample of the Area A Kanne chamber data.

The two Kanne chambers in Area A are sampling air from the area immediately surrounding the chambers, along the north and south catwalks of Area A. The chambers are subject to three separate sources of radiation: (1) prompt radiation generated by the beam, (2) "shine" from gamma radiation in ambient radioactive room air, and (3) the radioactive air within the chamber. The total current measured by the Kanne chamber and electrometer, $I_{total}$, is made up of these contributors as follows:

$$I_{total} = I_{prompt} + I_{shine} + I_{chamber}$$

where:

$I_{total}$ = total current generated in the Kanne chamber

$I_{prompt}$ = current from radiation generated by beam interactions

$I_{shine}$ = current from gammas in ambient room air ("room shime")

$I_{chamber}$ = current from radioactive air within the chamber

In order to show that the two-point sampling in Area A is representative of ambient Area A conditions, it is necessary to find the chamber air contribution as a function of Kanne chamber total current and demonstrate a uniform response. For each Kanne chamber, the chamber air contribution will scale (increase) with increasing radioactive gas concentration in the Area A building if the air is mixed and the monitoring locations are representative. The scaling factor is determined through analysis of the data.

Isolating the current from the air within the chamber ($I_{chamber}$) is a multi-step process.

The first step in analyzing the signal is to find an average value of $I_{prompt}$ for the run cycle. This is done through manual examination of the Kanne chamber strip charts. Beam-off events are readily apparent on the charts, due to the dramatic drop in the Kanne chamber current output, called the “prompt drop.” The magnitude of this prompt drop is equal to $I_{prompt}$. Not every beam-off will lead to a “useable” prompt-drop value; when the beam immediately turns back on, the prompt drop may not be indicative of the actual $I_{prompt}$ contribution. Superior prompt drop events occur when the Kanne chamber output current is fairly steady, the beam turns off and a prompt drop occurs, and the beam stays off for a period of time. In these cases, one can observe the $I_{total}$ value, the prompt drop ($I_{prompt}$), and then the decay away of the activity in the room and chamber air.

Note that if the accelerator operates at a fairly steady beam current for the entire run cycle, a simple value of average $I_{prompt}$ can be used, equal to the average prompt drop value.

If the accelerator beam current varies greatly throughout the run cycle, a more complex methodology must be used to determine average $I_{prompt}$. A number of prompt drop values should be noted over the run cycle, along with the accelerator beam current at the time. With this information, one can find a ratio of $I_{prompt}$ to the ion beam current at each point. This ratio is averaged over the run cycle, or other time period of interest. To find the average value of $I_{prompt}$, this average ratio can be multiplied by the average accelerator beam current for the time period. This is noted in the equation below.

$$\overline{I_{prompt}} = \overline{\left(\frac{I_{prompt}}{J_{beam}}\right)} * \overline{J_{beam}}$$

Where:

| | |
|---|---|
| $\overline{I_{prompt}}$ | Is the average prompt component of the Kanne chamber's total current output |
| $\overline{\left(\frac{I_{prompt}}{J_{beam}}\right)}$ | Is the Kanne current's prompt component at each point, divided by the LANSCE beam current at that point; then averaged over the time period of interest. |
| $\overline{J_{beam}}$ | Is the average LANSCE beam current for the time period of interest |

This average value of the prompt contribution is subtracted from every data point in the applicable time period, leaving each data point as the sum of the room shine and chamber air components, as shown below.

$$I_{total} - \overline{I_{prompt}} = I_{chamber} + I_{shine}$$

Now the chamber air contribution, $I_{chamber}$, must be isolated from the resulting net current. This is accomplished by finding the average ratio of the chamber air signal to the sum of the chamber air and room shine signals.

An automated valve system has been constructed an implemented, which flushes the Area A Kanne chambers air with "fresh" air from outside the building. This flushing occurs once per hour, for 10 minutes. During these flush periods, the current detected by the chamber is composed of the prompt signal and the room shine components only; it is assumed that the outside air is not radioactive. When this flushing occurs, the current will drop from its steady-state value. This "fresh air drop" is the difference in recorded current between normal sampling and that when fresh outside air is flushing the chamber. The magnitude of the fresh air drop is equal to the chamber air contribution, and is the primary basis for concentration measurements in Area A.

Fresh air drops should be easily recognizable by their unique "notch" shape on the chart. Also, a second plotter on the chart indicates the start & end of each flushing event.

Once the prompt component is subtracted from the Kanne chamber output current, the resulting net current value is from the chamber air and the room shine components, as described above. The magnitude of each fresh air drop (equal to $I_{chamber}$) is divided by this net current signal ($I_{chamber} + I_{shine}$). This ratio is then averaged over the run cycle or applicable time period.

Multiplying the net current ($I_{chamber} + I_{shine}$) by this ratio isolates the $I_{chamber}$ component from the net current. This final component can then be integrated over the applicable time period to determine net charge collected by the Kanne chamber, from air in the ionization chamber.

In summary, the analysis of the Area A Kanne chamber total current is done as follows: the average prompt signal is subtracted from the total current, and the difference is multiplied by the ratio of the average fresh air drop to the "chamber plus shine" current.

This final result is the net current measured from air within the chamber, and can be integrated to find total charge collected from Kanne chamber air. This is as demonstrated in the equation below.

$$\left(I_{total} - \overline{I_{prompt}}\right) * \overline{\left(\frac{I_{chamber}}{I_{chamber} + l_{shine}}\right)} = I_{chamber}$$

Integration of $I_{chamber}$ is done by multiplying each $I_{chamber}$ value by the time increment for which it is applicable. This results in a value of charge collected (picocoulombs). The charge collected for each time increment is added together to determine charge collected for the run cycle.

2. **Area A-East Analysis**

The other diffuse sources requiring an analysis of the Kanne signal are Area A-East and the Line A beam tunnel (if monitored). The Kanne chambers monitoring these areas are located in Area A-East, and are subjected to a room shine component. Due to the large amounts of shielding between the beam line and the Kanne chambers, the prompt background signal is not significant. To find the correction factor for these diffuse sources, fresh outside air is flushed through the chambers, so only the room shine contribution was recorded by the chamber. A correction factor was found, as follows:

$$\text{Room shine correction factor} = \frac{I_{total} - I_{shine}}{I_{total}}$$

This correction factor can be treated as a simple percentage of the total signal that is from air in the chamber, not from room shine.

3. **Analysis of other diffuse sources**

The other diffuse sources do not require this analysis process, due to two factors. First, the other chambers are not located in the area they are sampling; the radioactive air measured in the chamber is drawn from the source area through rubber hose, and returned to the source area in the same manner. This removes the “room shine” component of the signal. Second, the other Kanne chambers are located in areas that are shielded from beam interactions with targets or beam line components, unlike in Area A. This removes the prompt contribution from the signal. For these areas, the entire current recorded by the Kanne chambers is assumed to be from the air within the chamber, and can be directly integrated to find the charge collected.

## C: Converting charge collected to activity

In the early 1990’s, a 50 liter Kanne chamber was calibrated with radioactive air at the LANSCE ES-03 stack in order to determine the calibration factor from charge collected to activity. Radioactive air that was primarily carbon-11 (and argon-41, to a much lesser extent) flowed through the Kanne chamber and the resulting current recorded. This current was integrated over the time of testing, yielding a total charge collected. The air simultaneously flowed through the stack's gamma detection system, consisting of a known-volume "gamma can" viewed by a high-purity germanium (HPGe) detector with multichannel analyzer software. The 511 keV gamma counts were accumulated over the same period. The absolute efficiency of the detector is well known for the gamma can. Combining this with the charge from the Kanne chamber, the calibration factor, k, was obtained in units of activity per charge per flow rate. This historical value of k is equal to $2.62*10^{-6}$ (microCi/(pC*cm$^3$/sec).

In 1998, this calibration factor was calculated from principles discussed in Hoy, 1961. The calculated value (2.16E-6) is similar (within 20%) to the historical value, with differences likely due to assumptions of ion chamber efficiency. The calibration factor was also measured with a 50 L Kanne chamber in use at the ES-2 stack, which is in series with a HPGe detector. Based on the 1997 through 1999 operating periods, the measured calibration factor is 2.84E-6, within 10% of the historical value. This measured value, being slightly more conservative than the historical value, has been used since 1998 through 2002.

The process of using a Kanne chamber in series with a high purity germanium (HPGe) detector is further described in the procedures for determining gaseous emissions of radionuclides. The Kanne chamber's output current is a real-time measure of radionuclide concentration in the air in the chamber. This current can be integrated to determine total charge collected by the Kanne chamber & electrometer, which is proportional to the total amount of radioactive material that went through the Kanne. The integrated charge is multiplied by the calibration factor and the source's outflow (discussed in the next section) to obtain the total activity released from the diffuse source.

To find the radiological composition of the diffuse emissions, decay curves can be taken with the Kanne chambers. Alternatively, a HPGe detector and multichannel analyzer can be used to obtain a more accurate assessment of the composition. Each source's composition is determined to find released activities of different nuclides (see section III-E).

The released activities are modeled with the CAP88 code to determine offsite dose from the diffuse releases. Population and meteorological data are identical to those used for stack release analysis, but different release heights and release velocities are used as inputs to the code.

## *V: Determining building outflow*

### A: Ventilated buildings

For buildings which are subject to ventilation, it is assumed that the air flow out of the building is equal to the airflow into the building through the ventilation system. Building inflows are measured by Johnson Controls Northern New Mexico (JCNNM), LANL's engineering support contractor. In this situation, the building outflow (through doors, cracks in walls, etc.) is assumed to be equal to the building inflow through the ventilation system. This situation applies only to Area A, where the total inflow has been measured at 115,635 cubic feet per minute.

Area A has six air supply fans, each of which was separately measured by JCNNM to determine individual flow rates. Mechanical failure of a fan component can cause a fan not to function. For the time period over which a fan is non-operational, the building outflow is reduced by that fan's contribution. The individual fan flow rates (in cubic feet per minute, as historically measured by JCNNM) are as follows.

| Fan Designations | | Flow Rate (actual cfm) |
|---|---|---|
| HV-1 | FAR-17 | 25097 |
| HV-2 | FAR-2 | 24331 |
| HV-3 | FAR-5 | 15744 |
| HV-4 | FAR-9 | 9131 |
| FS-6 | FAR-14 | 20029 |
| FS-7 | FAR-13 | 21303 |

TOTAL: 115635 cfm (actual)

Note: The "actual" term in the flow rate unit indicates a flow rate of air at local pressure and temperature, the same as the air in the Kanne chambers. The unit of "actual cubic feet per minute" is abbreviated "acfm."

Using the flow rate of 115635 acfm is conservative, due to emission of some of Area A air out of the ES-03 stack and migration of air into Area A-East (see section B.1, below). The outflow from Area A for diffuse emission concerns is therefore estimated to be **115,000 acfm.**

The 1L Service Area (1LSA) is ventilated through a vent in the roof of the Mechanical Equipment Building (TA-53-7-200, the MEB). This fan system exhausts both Experiment Room-1 (ER-1) and the 1LSA. The exhaust fan design flow rate of this system is **12,000 acfm**. While a portion of this flow is from ER-1, assuming it all comes from 1LSA is quite conservative.

## B: Non-ventilated buildings

Each non-ventilated source is analyzed separately, due to the different parameters associated with the source. These parameters can include building physical size, construction materials, location with respect to other buildings, and susceptibility to wind conditions. Descriptions of each source's airflow analysis follow.

### 1. Area A-East

Area A-East was originally not an enclosed structure. The A6 beam stop area and the line A beam tunnel were not enclosed inside a building. The building was erected around these facilities in the 1970's. The resulting structure is a room approximately 194 feet long, 72 feet wide, and 32 feet in height, giving a gross volume of 447,000 ft$^3$. About 10% of this volume is taken up by shielding blocks, room M320, and the remote handling trailer. The resulting volume is 402,000 ft$^3$. There are eight crane support pillars spaced along the east-west length, about 32 feet apart. These pillars are used as reference points when taking measurements of room air concentrations.

The primary source of diffuse emissions is the A-6 beam stop, which is located on the eastern edge of the Area A-East building. The beam stop is covered by a shield-block structure known as the doghouse. One Kanne chamber in AAE, designated as the "A6 Kanne," continuously monitors air above the doghouse, while another, designated as the "AAE Rover," monitors air near the center of AAE or other areas of interest. Only the A6 Kanne is used for diffuse emissions reporting purposes, since it measured the "hot spot" above the A6 beam stop. Kanne chamber measurements made throughout the building indicate that the A6 Kanne typically reads 3 times higher at its standard monitoring location than at other locations in AAE. To account for this non-homogeneous distribution of air, outflows are reduced by a factor of three. Alternatively, the A6 activity could be reduced by a factor of three, with the same net result.

The outflow from Area A-East is a result of two factors. First, inflow from Area A (next to AAE to the west) and the Staging Area (beside AAE to the north) displace AAE air and drive it out to the atmosphere. Second, winds cause outflow from the building.

Air flow measurements for Area A-East were made with a hot-wire anemometer. These measurements are based on standard air pressure (14.7 psi) and 70 degrees Fahrenheit temperatures. The measured flows are adjusted upward to account for the average atmospheric conditions at LANSCE. The conversion to "typical" Los Alamos values of 11.2 psi and 75 deg. Fahrenheit is a factor of 1.32.

To determine inflows to Area A-East from Area A, assume that half of the Area A ventilation goes out through vents in the roof. The remaining half goes through holes and cracks in the walls, doors, etc. To find the portion of Area A air flowing into AAE, multiply this remaining airflow (57500 cfm) by 10%, the amount of Area A that shares a common surface with AAE. This final inflow from Area A into AAE is 5750 acfm, assuming all six ventilation units in Area A are in full operation. Due to this rather low flow rate and the large volume of Area A-East, radioactive air from Area A will be decayed away by the time it reaches the far east end of AAE, where the A6 Kanne is monitoring. No adjustments to the A6 Kanne signal need to be made.

Inflow from the staging area (north of Area A-East) into AAE at the major inflow points was measured in 1993 to be 1239 acfm. This value was doubled to account for a variety of smaller, nonmeasurable inflows. In 1994, sealing efforts were performed on the major inflow points. It is estimated that the total inflow from the staging area to AAE was halved by these efforts. The total inflow from the staging area to AAE is now taken to be 1239 acfm.

Inflows from the staging area and Area A are summed together and assumed to displace AAE air at an equal rate. The total outflow resulting from Area A and the staging area inflows is then approximately 7000 acfm.

Outflows due to windy weather are equivalent to two air changes per hour (13,300 cfm). This value was determined in discussions with a heating/ventilating engineer, and by air leakage estimations performed by the Radian Corporation. Windy conditions occur about one third of the time; this value is verified through wind roses and other meteorological parameters. Windy conditions can also be seen as variations in the Kanne chamber signal recorded on strip charts. The strip charts confirm the one third estimation. Average outflow due to wind can therefore be estimated as one-third of two air changes per hour, or 4433 acfm.

By combining these parameters, the long-term average outflow from Area A-East is calculated to be equal to 11,400 cfm. Since only one third of the building has significant concentration, this outflow is divided by three to equal **3800 cfm**.

## 2. Isotope Production Building

The isotope production facility (IP) is located north of Area A-East and east of the staging area. It has an approximate volume of 13,400 $ft^3$. Its east and west walls are solid poured concrete, and the south wall is the shielding for the A6 beam stop. The only sources for diffuse air emissions are therefore the north wall and the roof.

Extensive sealing work was done on the IP building during 1993 and 1994 maintenance periods. Visible cracks and penetrations were sealed as well as the roof soffit. The building was checked with a smoke release and found to be quite tight.

An opening on the north wall for the isotope production stringers to enter the building is the major source of outflow for the IP building. In 1993, the flow through this stringer opening was measured at 270 actual cfm during south wind conditions, and emissions were correlated with this flow. For all other winds, the flow was 10% of this value, or 27 acfm. Before the 1994 run cycle, the stringer opening was sealed as well as was practical. The radioactive air concentration was checked when radioactive gas was present, and the sealing was found to be very effective. The concentrations measured after sealing were a factor of 10 higher than pre-sealing, so the resulting outflow is estimated at 10% of 1993 levels, 27 acfm.

There is a weather driven air change as well during southerly wind conditions, estimated at 2 air changes in 5 hours. This comes to a flow of 90 cfm, and is additional to the flow out of the sealed stringer housing. The flows are summarized as follows:

| | Southerly winds | All other winds |
|---|---|---|
| Stringer Housing | 27 acfm | 3 acfm |
| Weather-driven change | 90 acfm | 0 acfm |
| **TOTAL:** | **117 acfm** | **3 acfm** |

Using meteorological data that the southerly wind blows one-third of the time, this averages out to a continuous outflow of **41 cfm**.

## 3. Beam Switchyard

The beam switchyard (SY) is an underground tunnel where the ion beams divide into lines A, D, and X. The dimensions of the tunnel are approximately 9 feet high by 15 feet wide by 200 feet long, for a volume of 27,000 $ft^3$.

When radioactive air leaves the switchyard, the destinations for the exhaust gas include the following:

a) the linear accelerator tunnel, which has no release; all gas decays away.
b) the line B tunnel, which is evacuated by ES-03. All emissions detected by stack monitoring systems.

c) the line D-North tunnel. Although a ventilation barrier is present, gas in this tunnel can slowly migrate to the ES-2 stack in building 7.
d) vertical vent shafts into the sector S building
e) out the line D access door and the truck access door

All pathways are accounted for except for options (d) and (e). Both the line D access door and the truck access door were sealed before 1995 operations. It is assumed that half of the outflow air will go out through pathways (d) and (e).

The modeling scenario examines migration of gas through the tunnel, regardless of the cause. It takes an average of 10 minutes (measured) for radioactive gas to migrate from the primary source (the A1 target cell) to the switchyard area. Using the 27,000 $ft^3$ volume of the switchyard, this gives a flow rate of 2700 cfm. Again, assuming half of the gas flows out non-monitored pathways, an emission rate of 1350 cfm results. Since one third of the time westerly wind causes the gas to flow from the switchyard east into the A1 target cell (which is evacuated by the ES-03 stack), this emission rate is multiplied by a factor of two thirds (0.667). The final adjusted emission rate is **900 cfm**.

This outflow was re-calculated during analysis of 1998 emissions, using measured activities and clearance rates. The outflow due to ventilation in 1998, through non-monitored points, was measured to be 799 cubic feet per minute. Since the historical value of 900 cfm results in a higher released activity, the conservative historical value was retained.

## 4. Line A Beam Tunnel (A4/A5)

The line A beam tunnel from Area A to the A6 beam stop is a poured concrete structure 8 feet high by 8 feet wide by 140 feet long, for a total volume of 8960 cubic feet. Historically the tunnel has been divided into two sections, designated A4 and A5. The tunnel cross section is uniform except for two segments, one at A4 called the “A4 Stubout” and one at A5.

The A4 stubout extends 24 feet along the south wall and is 8 feet high. This portion of the tunnel wall is constructed from concrete shield blocks stacked to form a solid wall with an access door and entrance maze behind the door providing access to the tunnel. The stacked stubout wall forms the north wall of the stubout enclosure building with approximate dimensions of 24 feet x 20 feet x 10 feet. The stubout enclosure building is also constructed from concrete shield blocks with a roof, and houses various pieces of mechanical equipment such as vacuum pumps, a compressor, etc.

The A5 segment that is not solid concrete is the roof of the beam tunnel, measuring 8 feet x 35 feet. This segment has large concrete shield blocks (called doors) which form the roof of the beam tunnel. Additional concrete blocks are stacked on top of the A5 doors to provide radiation shielding.

Outflow of radioactive air through solid poured concrete is not possible. The only escape pathways for radioactive air are therefore through cracks between stacked shield blocks at the A4 stubout and at A5. Since the beam tunnel is not actively ventilated, outflow will be primarily due to weather and convective effects. During southerly wind conditions, outflow through the A4 stubout portion is not possible, since the only opening is to the south (air cannot flow out *against* the direction of the wind). The 8 feet x 8 feet west end of the beam tunnel at A4 is solid stacked steel and concrete, the beam tunnel stops at that point. Continuing west toward Area-A for about 30 feet there is only room for the 12 in. diameter beam pipe. The very small volume around the beam pipe is packed with metal wool. Any outflow through the west wall could be vertical into the A-East building which is monitored or to the north into the staging building where the gas would decay away. Previously it was determined that air flows from the staging building into A-East which is monitored (part of the outflow from A-East is due to inflow from the staging area). Outflow to the south is not practical for the reason stated above. At A5, for south wind, outflow through the stacked shielding on top of the tunnel can in principle be vertical or to the north. Vertical flow would be into the A-East building, flow to the north would be into the staging building. Outflow to the south is not practical for the reason stated above. The beam tunnel is covered with earth fill and is housed inside the A-East building (on top) and the staging area building on the north side. During non-south wind, wind effects are moderated because of the A-East and staging area buildings. Outflow that may occur from A4 would be into the A4 stubout enclosure where additional delay would occur allowing the radioactive air to decay before migrating out the enclosure. At A5, vertical outflow would be into A-East, outflow to the south would be to the outside and would cause emissions.

The above considerations indicate that there is little or no unmonitored emission during south wind. Outflow during non-south wind is estimated by scaling according to the relative areas where outflow may occur (at the A4 stubout and A5) to the area of the beam tunnel (top and side). The area of the beam tunnel is: top 8 feet x 140 feet = 1120 feet$^2$ and sides 8 feet x 140 feet = 1120 feet$^2$. The A4 stubout area is 8 feet x 24 feet = 192 feet$^2$ and the A5 roof area is 8 feet x 35 feet = 280 feet$^2$. To estimate outflow use two air changes per hour scaled by the ratio of the areas. Two air changes per hour for the entire tunnel corresponds to a flow of 2 x 8960 feet$^3$/hr. = 17920 feet$^3$/hr. or 299 cfm. Two air changes per hour should overestimate since it applies to exposed structures (not those that are inside or shielded by another structure) during windy conditions. Non-south wind occurs two thirds of the time for all wind speeds based on 1995 meteorological data during the operating period. Applying this two-thirds factor for the entire operating period is conservative since it includes all winds speeds and all non-south winds.

Outflow resulting from two air changes per hour based on the total volume of the tunnel (299 cfm):

A4: A4 area/area of one side = 192 feet$^2$/1120 feet$^2$ = 0.17
A5: A5 area/area of tunnel top = 280 feet$^2$/1120 feet$^2$ = 0.25

A4 outflow = (2/3)x(299 cfm x 0.17) = 33.9 cfm
Recall the 2/3 factor because non-south wind occurs two thirds of the time.

A5 outflow = (1/2) x (2/3)x(299 cfm x 0.25)= 24.9 cfm
For A5, half the outflow is vertical into A-East the other is out.

**Total line A outflow = A4 + A5 = 58.8 cfm**

A second estimate can be made using two air changes per hour based on the local volume at A4 and A5.

A4: local volume 8 feet x 8 feet x 24 feet = 1536 $feet^3/hr$.

two local air changes per hour = 2 x 1536 $feet^3/hr$.

= 51.2 cfm

A5: local volume 8 feet x 8 feet x 35 feet = 2240 $feet^3/hr$.

two local air changes per hour = 2 x 2240 $feet^3/hr$

= 74.7 cfm

Scale the local air changes for each area.

A4: 1/3(51.2 cfm) = 17.1 cfm

The 1/3 factor results from outflow through the south side only; the top and north side is solid concrete.

A5: (1/2) x 1/3(74.7 cfm) = 12.4 cfm

For A5, half the outflow is into A-East the other is out.

Total outflow = (2/3)x (A4 + A5) = 19.7 cfm

Recall the 2/3 factor because nonsouth wind occurs 2/3 the time.

Of the two estimates, the first gives a larger (more conservative) outflow so use the larger value of 58.8 cfm, rounding it to 60 cfm.

## 5. Summary

A final outline is given in the following table. The numbers are rounded for ease of calculation.

**Summary of Diffuse Source Outflows**

| Building | Outflow (acfm) |
|---|---|
| Area A (AA) | 115,000 |
| Area A-East (AAE) | 3800 |
| Isotope Production (IP) | 41 |
| Beam Switchyard (SY) | 900 |
| Line A Beam Tunnel (A4/A5) | 60 |
| 1L Service Area (1LSA) | 12,000 |